# The effect of a traditional low-fat diet on energy and protein intake, serum albumin concentration and body-weight in Ugandan preschool children

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1. A group of ten Ugandan children were given, *ad lib.*, under supervision, the traditional home diet and their intakes of energy and protein and changes in body-weight and concentrations of serum albumin compared with those of a similar group of nine children fed on a milk-based diet with the same protein concentration.

2. The energy and protein intakes of the children fed on the home diet were significantly lower than those of the children fed on the milk-based diet, as was their rate of weight gain and serum albumin regeneration.

3. The significance of the findings is discussed in relation to the low intakes of energy and protein and the hypoalbuminaemia found in Ugandan preschool children.

The relatively low protein content of largely vegetable diets based on staples such as plantain, sweet potato, cassava and yams has for some time been considered to be a major factor in the development of kwashiorkor. Other features of these diets such as the low-fat content and consequent bulkiness, however, may be equally important in that they may effectively limit the amount of such diets which can be consumed by young children (Nicol, 1971).

In a detailed study of the diets of Ugandan children during the first 3 years of life it was found that protein concentration was not particularly low, providing 8–10% of total energy (I. H. E. Rutishauser, in preparation), but that energy intake was, on average, only 70% of the recommended levels, although the actual quantity of food consumed by the children was, if anything, greater than that consumed by European children of the same age (Ministry of Health, 1968; Rutishauser & Whitehead, 1972). Progressive hypoalbuminaemia was common and frequently associated with infection (Frood, Whitehead & Coward, 1971; Poskitt, 1971), but rates of growth were essentially normal in the 2nd and 3rd years of life, although 'catch-up' growth after an infection might be slow.

It seemed that the diets might be adequate to support normal growth and to maintain serum albumin concentration in the absence of infection but inadequate to enable correction of hypoalbuminaemia and to permit rapid 'catch-up' growth. It was decided, therefore, to feed, under supervision, a group of children with moderate hypoalbuminaemia on a diet similar to that which they normally received at home, on an *ad lib.* basis, to find out how much of the diet was consumed and what effect this had on serum albumin concentration and body-weight. A comparison was also made with children receiving a milk-based diet providing a similar percentage of energy from protein.

EXPERIMENTAL

Nineteen children attending the Child Nutrition Unit's rural child welfare clinic at Namulonge near Kampala, who were aged between 1 and 3 years and had early clinical signs of malnutrition or a history of intermittent swelling and failure to gain weight, were admitted, together with an attendant, to the Unit's metabolic ward in Kampala. All had moderate hypoalbuminaemia with serum albumin concentrations between 18 and 31 g/l. The first nine children admitted were given a liquid milk-based preparation containing full-cream milk powder, sucrose and cottonseed oil which provided 8% of its energy as protein. The milk-based diet was given at the rate of 100 ml/kg body-weight per d and provided 2 g protein and 418 kJ/kg body-weight per d; the children were allowed to supplement this with as much plantain or sweet potato as they wished. The remaining ten children were given a diet providing 8% of its energy as protein, based on the foods normally consumed at home. Mixtures of plantain and sweet potato combined with either beans, groundnuts or meat were prepared in the Unit's kitchen and used in rotation; so beans and groundnuts were given on each of 3 d every week and meat on 1 d. In addition, the children were allowed daily 25 g sucrose in 500 ml tea and a small amount of sweet banana.

All the children were fed five times daily and received a routine vitamin and mineral supplement as described by Staff (1968). Those receiving the home diet were offered at each feed an amount of food which would, if consumed, have provided 2 g protein and 418 kJ/kg body-weight per d, as for the children receiving the milk-based diet. More was then given if this quantity was consumed. Samples of the different plantain and sweet potato mixtures were analysed at intervals during the course of the study, for total nitrogen by a semi-automated micro-Kjeldahl procedure (Fleck, 1967) and for energy content by bomb calorimetry (Miller & Payne, 1959). The experimental diets were offered for periods of 7–22 d and after that the children were given one of the standard 4 g protein/kg body-weight per d milk diets used in the treatment of kwashiorkor (Staff, 1968) for 3–11 d. While the children were in the Unit's ward they were not in bed during the day unless they were ill.

The children were weighed daily, without clothes, before the first meal of the day at 06.00 hours, on a Berkel Auto scale with a sensitivity of 10 g. Blood samples were obtained by venepuncture on admission and subsequently twice a week. Serum albumin was measured by a microautomated technique based on the dye-binding of albumin with 2-(4′-hydroxyazobenzene)-benzoic acid, developed by Coward, Sawyer & Whitehead (1971).

The energy and protein content per kg of the various home diet mixtures and of the milk-based diet as consumed are shown in Table 1, and the proportions of total energy, in each, derived from protein, fat and carbohydrate. The essential difference between the various mixtures constituting the home diet and the milk-based one was in the proportion of total energy derived from fat. The home diet mixtures provided only 2–18% of the energy from fat, whereas the milk-based diet provided 66% of the energy from this source. In terms of protein and energy content per kg the milk-based diet fell within the range of the home diet mixtures.

Table 1. *Energy and protein content/kg and percentages of total energy derived from protein, fat and carbohydrate in the various home diet mixtures and the milk-based diet*

| Diet mixture | Energy (kJ) | Protein (g) | Percentage energy from: Protein | Fat | Carbohydrate |
|---|---|---|---|---|---|
| Plantain and groundnuts | 4561 | 24 | 9 | 15 | 76 |
| Plantain and beans | 3933 | 23 | 10 | 2 | 88 |
| Plantain and meat | 3724 | 20 | 9 | 6 | 85 |
| Sweet potato and groundnuts | 6360 | 30 | 8 | 18 | 74 |
| Sweet potato and beans | 5356 | 29 | 9 | 3 | 88 |
| Sweet potato and meat | 4728 | 26 | 9 | 7 | 84 |
| Milk-based diet | 4184 | 21 | 8 | 66 | 26 |

Table 2. *Mean values and standard errors for age, body-weight and crown–heel length as a percentage of standard and serum albumin in the two groups of children on admission*

| Group | No. of children | Age (months) | Body-weight (as % of standard*) | Crown–heel length (as % of standard*) | Albumin (g/l) |
|---|---|---|---|---|---|
| Children given home diet | 10 | 24 ± 2 | 81 ± 5 | 89 ± 2 | 26 ± 1 |
| Children given milk-based diet | 9 | 21 ± 2 | 71 ± 4 | 91 ± 2 | 23 ± 1 |
| | | NS | NS | NS | NS |

NS, mean values for the groups not significantly different by Student's *t* test.
* See Tanner *et al.* 1966.

Table 3. *Intercurrent infections and infestations found in the two groups of children on admission*

| Children given home diet: Subject | Diagnosis | Children given milk-based diet: Subject | Diagnosis |
|---|---|---|---|
| 2135 | Hook-worm | 2086 | Bronchiectasis, hook-worm |
| 2137 | Otitis, hook-worm, ascariasis, strongyloidiasis | 2088 | Pulmonary tuberculosis |
| 2139 | Otitis | 2094 | Hook-worm |
| 2151 | Urinary infection | 2099 | Malaria, hook-worm, ascariasis |
| 2160 | Hepatosplenomegaly | 2110 | Pneumonia |

In Table 2 the two groups of children are compared on the basis of age in months, body-weight and crown–heel length as a percentage of standard (Tanner, Whitehouse & Takaishi, 1966) and serum albumin concentration on admission. In respect of these criteria there were no statistically significant differences between the groups. Intercurrent infections and infestations were found in about half the children in each group on clinical and routine laboratory examination on admission. These findings are detailed in Table 3.

## RESULTS

The mean daily energy and protein intakes per kg body-weight, daily changes in serum albumin concentration and body-weight for the individual children in the two groups, over the whole period for which they were receiving the experimental diets, are shown in Table 4. Energy and protein intakes were significantly lower in the

Table 4. *Mean daily intakes of energy and protein/kg body-weight, and daily changes in serum albumin and body-weight for the whole period for which the children were receiving diets supplying 8% of the energy as protein*

| Subject | Period (d) | Energy intake (kJ) | Protein intake (g) | Change in albumin (mg/l) | Change in body-wt (g) |
|---|---|---|---|---|---|
| | | | Home diet | | |
| 2135 | 14 | 569 | 2·6 | +310 | +45 |
| 2137 | 18 | 393 | 1·8 | +250 | +18 |
| 2139 | 15 | 377 | 1·7 | +30 | +29 |
| 2146 | 22 | 439 | 2·1 | +250 | +22 |
| 2151 | 7 | 238 | 1·0 | −200 | −20 |
| 2160 | 17 | 326 | 1·4 | −180 | +18 |
| 2170 | 8 | 510 | 2·5 | −390 | +75 |
| 2173 | 14 | 582 | 2·6 | +110 | +50 |
| 2176 | 13 | 201 | 0·9 | +510 | −54 |
| 2180 | 14 | 444 | 2·1 | +110 | +58 |
| Mean and SE | | 410±42 | 1·9±0·2 | +80±90 | +24±12 |
| | | | Milk-based diet | | |
| 2084 | 12 | 460 | 2·2 | +490 | +60 |
| 2086 | 13 | 657 | 2·7 | +550 | +58 |
| 2088 | 14 | 661 | 2·7 | +520 | +60 |
| 2089 | 14 | 590 | 2·5 | +410 | +76 |
| 2091 | 12 | 632 | 2·6 | +830 | +52 |
| 2094 | 11 | 636 | 2·6 | +950 | +106 |
| 2099 | 14 | 552 | 2·4 | +840 | +63 |
| 2100 | 14 | 452 | 2·2 | +1230 | +103 |
| 2110 | 12 | 569 | 2·4 | +650 | +117 |
| Mean and SE | | 577±25 ** | 2·5±0·1 * | +720±90 *** | +77±8 ** |

Mean values significantly different for the two diets by Student's $t$ test: * $P<0·05$; ** $P<0·01$; *** $P<0·001$.

children receiving the home diet. All the children in the group receiving the milk-based diet achieved intakes of over 418 kJ/kg body-weight per d but only five of the ten children in the group receiving the home diet had intakes of this order and in two children the intake was only about 209 kJ/kg body-weight per d. Similarly, all the children receiving the milk-based diet had protein intakes greater than 2 g/kg body-weight per d, but only five of the children receiving the home diet had intakes of 2 g protein/kg body-weight per d.

The mean daily increase in serum albumin concentration was significantly greater in the children receiving the milk-based diet, as might be expected from their energy and protein intakes. Unexpectedly, however, the greatest daily increase in serum albumin concentration was recorded, in each group, in the child with the lowest intake of energy and protein. In the child receiving the home diet, who also lost a considerable amount of weight although he had only minimum clinical oedema and did not have diarrhoea, the increase in serum albumin concentration was accompanied by a rise in haemoglobin concentration and packed cell volume, indicating haemoconcentration. In the child receiving the milk-based diet there was no corresponding increase in haemoglobin concentration and packed cell volume, and his rapid rate of weight gain

Table 5. *Mean daily intake of solid foods by the children while receiving diets supplying 8% of the energy as protein, in g and as g/kg body-weight*

| Group | Subject | Intake of solid foods (g) | Intake of solid foods (g/kg body-wt) |
|---|---|---|---|
| Home diet | 2135 | 1260 | 124 |
| | 2137 | 743 | 85 |
| | 2139 | 646 | 76 |
| | 2146 | 876 | 87 |
| | 2151 | 495 | 42 |
| | 2160 | 512 | 59 |
| | 2170 | 724 | 96 |
| | 2173 | 470 | 92 |
| | 2176 | 453 | 37 |
| | 2180 | 987 | 89 |
| Mean and SE | — | 717 ± 83 | 79 ± 8 |
| Milk-based diet | 2084 | 92 | 12 |
| | 2086 | 381 | 57 |
| | 2088 | 423 | 61 |
| | 2089 | 459 | 43 |
| | 2091 | 491 | 56 |
| | 2094 | 389 | 52 |
| | 2099 | 221 | 29 |
| | 2100 | 184 | 18 |
| | 2110 | 334 | 38 |
| Mean and SE | — | 330 ± 45 | 41 ± 6 |

was probably at least partly due to rehydration since he had had a severe episode of diarrhoea shortly before admission. Conversely, the greatest fall in serum albumin concentration, in the group receiving the home diet, occurred in a child with one of the highest intakes of energy and protein, and the highest rate of weight gain. Clinical and routine laboratory examination on admission showed no abnormalities other than a trace of albumin in the urine, and his albumin concentration subsequently increased satisfactorily on the 4 g protein/kg per d diet.

Increase in body-weight was also significantly greater in the children receiving the milk-based diet. None of the children in this group had a total loss of weight over the period for which they were receiving the milk-based diet, as did two of the children receiving the home diet. The intakes of energy and protein of these two children were the lowest in the group and one of the children (2151) also had a urinary infection.

Although the children receiving the home diet had lower intakes of energy and protein, the total amount of solids and water consumed was similar in both groups. The mean daily intake of solids in the children receiving the home diet was 218 g and in the children receiving the milk-based diet 228 g; the mean daily intakes of water were 998 and 935 g respectively.

The intakes of the liquid components of the diets, the milk preparation for the milk-based diet and tea for the home diet, were prescribed by the experimental procedure and amounted to 830 and 500 ml/d respectively. The intake of solid foods, in g per d and g/kg body-weight per d, by the individual children in both groups, is

Table 6. *Mean daily intakes of energy and protein/kg body-weight, and daily changes in serum albumin and body-weight for the period for which the children were receiving the diet providing 4 g protein/kg per d*

| Subject | Period (d) | Energy intake (kJ) | Protein intake (g) | Change in albumin (mg/l) | Change in body-wt (g) |
|---|---|---|---|---|---|
| | | | Previous home diet group | | |
| 2135 | 7 | 594 | 4·5 | +1500 | +100 |
| 2137 | 7 | 439 | 4·3 | + 140 | +104 |
| 2139 | 4 | 473 | 4·5 | +1580 | − 10 |
| 2146 | — | — | — | — | — |
| 2151 | 7 | 456 | 4·1 | + 90 | +107 |
| 2160 | 7 | 602 | 4·7 | + 390 | +101 |
| 2170 | 7 | 523 | 4·3 | + 310 | + 30 |
| 2173 | 7 | 561 | 4·4 | + 390 | + 29 |
| 2176 | 11 | 552 | 4·4 | + 640 | +127 |
| 2180 | 5 | 510 | 4·3 | + 500 | + 56 |
| Mean and SE | | 523 ± 21 | 4·4 ± 0·1 | +620 ± 180 | +72 ± 16 |
| | | | Previous milk-based diet group | | |
| 2084 | 6 | 410 | 4·2 | + 280 | + 27 |
| 2086 | 7 | 607 | 4·3 | +1240 | + 89 |
| 2088 | 7 | 569 | 4·3 | +1830 | +123 |
| 2089 | 7 | 506 | 4·3 | + 710 | + 54 |
| 2091 | 8 | 540 | 4·5 | +1180 | + 90 |
| 2094 | 3 | 519 | 4·4 | + 100 | + 20 |
| 2099 | 7 | 506 | 4·3 | + 810 | +167 |
| 2100 | 7 | 360 | 3·6 | − 290 | + 40 |
| 2110 | 5 | 594 | 4·5 | +1440 | +160 |
| Mean and SE | | 510 ± 29 NS | 4·3 ± 0·1 NS | +810 ± 230 NS | +86 ± 18 NS |

NS, mean values not significantly different for the two groups by Student's *t* test.

shown in Table 5. Those consuming the home diet ate at least 450 g/d and one child consumed nearly three times this quantity. The mean intake by the group as a whole was over 700 g/d. The mean intake of solid foods by the children receiving the milk-based diet was only just over 300 g/d. If the intake is expressed as g/kg body-weight per d the range of intake for the children receiving the home diet was 37–124 with a mean of 79, and that for the children receiving the milk-based diet 12–61 with a mean of 41.

To show that there was no essential difference between the two groups of children in terms of their ability to recover, progress was also compared over the period for which they were receiving 4 g protein/kg per d diet. Table 6 shows mean daily energy and protein intakes/kg body-weight, and daily changes in serum albumin concentration and body-weight over this period. There were no significant differences between the two groups of children with respect to energy and protein intakes or in changes in serum albumin and body-weight. Changes in both the latter, however, were very variable from one individual to another, despite consistently high intakes of energy and protein. A respiratory infection was diagnosed at the beginning of the 4 g protein/kg per d period in the only child who lost weight and in the four children whose mean increase in serum albumin concentration was less than 250 mg/l per d, one commenced treatment for a urinary infection (2151), two became pyrexial with respiratory infections (2137 and 2100), and one had loose stools (2094).

## DISCUSSION

Even when fed on their home diet, *ad lib.*, five times daily, only five out of the ten children achieved intakes of over 418 kJ and 2 g protein/kg body-weight per d during the period of the study. In four out of the five children failure to achieve an intake of this order could have been associated with an intercurrent infection, but the fifth child either would not or could not consume sufficient of the diet to do so. At home, children of this age are fed only once, twice or at the most three times daily and, according to the mothers, the amount of food offered is generally less than the amount that was being offered during the study. When questioned, the mothers all said that they thought we were giving too much food although they considered the food to be good food. It is thus not difficult to understand why children in their home environment frequently have what are generally considered to be low intakes of energy and protein (Rutishauser & Whitehead, 1972).

That, in the study, the children's intakes were limited by the type of diet and not by their physiological requirements was shown by the fact that the children receiving the milk-based diet all achieved intakes of over 418 kJ and 2 g protein/kg body-weight per d, despite episodes of infection in some of them which might have been expected to affect their appetite in a similar way to those experienced by the children receiving the home diet, and that when both groups of children were given the diet providing 4 g protein/kg per d there were no significant differences in energy and protein intakes.

Probably the most important factor in limiting not only the energy but also the protein intake of the children receiving the home diet was the low proportion of total energy derived from fat. If the home diet had provided 60% of the energy from fat together with 8% from protein, as did the milk-based diet, the children would have had to consume only 478 g/d to achieve an intake of 410 kJ and 1·9 g protein/kg body-weight per d instead of over 700 g of diet daily, or alternatively this amount of the home diet would have resulted in an intake of 611 kJ and 2·8 g protein/kg body-weight per d. In a recent study of English preschool children (Ministry of Health, 1968) the mean intake of foods, excluding milk, in children between the ages of 9 months and 5 years, was 540 g/d and, on average, 40% of the total energy was derived from fat. Quite obviously in the light of these figures a mean intake of over 700 g solid food daily must be regarded as a large intake and probably near to the maximum capacity of children aged 1–3 years, yet this amount of the home diet provided a barely adequate intake of protein and energy, as shown by the changes in serum albumin concentration and body-weight in the children in this study. Certainly, rapid regeneration of serum albumin was not achieved even on the quantities of home diet which could be consumed under the conditions of the study and which were more favourable than those generally encountered at home. Consequently, under home conditions any fall in serum albumin concentration, such as that associated with measles (Poskitt, 1971) and other infections, could easily lead to progressive hypoalbuminaemia in an environment where the incidence of infections is high (Frood *et al.* 1971).

Two other features in which the home diet differed from the milk-based one and which could have affected intake and serum albumin response must also be mentioned. First, the milk-based diet was largely a fluid diet and intake on this regimen might be expected to be less affected by anorexia associated with infection than that of the children receiving the home diet. It was, therefore, interesting to find that there was little difference in the mean daily intake of solids by the two groups of children. Secondly, the protein provided by the milk-based diet has a higher net protein utilization value than that provided by the home diet so that a greater proportion of the protein intake would have been retained and available for regeneration of serum albumin.

That the amount of milk consumed by preschool children has a pronounced effect on their total intake of energy and protein was shown quite clearly in a recent survey of English children (Ministry of Health, 1968), and there is little doubt that a fluid supplement to the home diet with a composition similar to that of cow's milk could be of great value in increasing energy and protein intake in Ugandan children. On the other hand, it is unlikely that improvement in protein quality or increase in protein concentration *per se* would have much effect in raising total energy intake unless accompanied by an increase in the proportion of total energy derived from fat, although regeneration of serum albumin would be more rapid provided that energy intake was above maintenance level.

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